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STUDY OF MONOPROPELLANTS FOR ELECTROTHERMAL THRUSTERS

DESIGN AND FABRICATION TASK SUMMARY REPORT

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J.D. Kuenzly

TRW Systems Group
One Space Park
Redondo Beach, Calif. 90278

JANUARY 1974

INTERIM REPORT

FOR PERIOD MAY - JULY 1973

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

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Prepared under the direction of C. K. Murch, Program Manager

16. Abstract

The objective of the "Study of Monopropellants for Electrothermal Thrusters" program is to determine the feasibility of operating small thrust level electrothermal thrusters with monopropellants other than MIL-grade hydrazine. The work scope includes analytical study, design and fabrication of demonstration thrusters, and an evaluation test program wherein monopropellants with freezing points lower than MIL-grade hydrazine are evaluated and characterized to determine their applicability to electrothermal thrusters for spacecraft attitude control.

Five demonstration thrusters were fabricated to determine the feasibility of operation with monomethylhydrazine, Aerozine-50, 77 percent hydrazine-23 percent hydrazine azide, and TRW formulated mixture of hydrazine monopropellants (MHM) consisting of 35 percent hydrazine-50 percent monomethylhydrazine-15 percent ammonia. The thruster design was based on the Electrothermal Hydrazine Thruster (EHT) developed by TRW for NASA/GSFC on NASA Contract No. NAS5-11477(1). The present thruster is designed to produce a steady-state thrust level of 0.344 N at 1.724×10^6 N/m^2 feed pressure. Vacuum specific impulse goals were set at 1961 N-s/kg steady-state and 1716 N-s/kg pulsed-mode (0.050 second to steady state)

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PREFACE

The objective of the "Study of Monopropellants for Electrothermal Thrusters" program is to determine the feasibility of operating small thrust level electrothermal thrusters with monopropellants other than MIL-grade hydrazine. The work scope includes analytical study, design and fabrication of demonstration thrusters, and an evaluation test program wherein monopropellants with freezing points lower than MIL-grade hydrazine are evaluated and characterized to determine their applicability to electrothermal thrusters for spacecraft attitude control.

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TABLE O. CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

This report summarizes the design and fabrication of demonstration thrusters in support of the "Study of Monopropellants for Electrothermal Thrusters" program. The design requirements, design rationale and fabrication methods are included in this report.

2.0 DESIGN

2.1 DESIGN OBJECTIVES

The thruster design was based on the Electrothermal Hydrazine Thruster (EHT) developed by TRW for NASA/GSFC on NASA Contract No. NAS5-11477. The upgraded design and performance requirements are listed below.

1. Thrust: 0.344 ± 0.0267N at 1.724 MN/m^2 nominal feed pressure
2. Vacuum specific impulse: 1961 N-s/kg steady state
   (goals) 1716 N-s/kg pulsed-mode
3. Pulse duration: 0.050 second to steady state
4. Pulse mode duty cycle: that typical for attitude control including "wheel dump"
5. Holding power: 5 watts maximum
6. Nominal voltage: 24 to 32 vdc
7. Maximum steady state on-time: 30 hours
8. Total number of pulses: 3×10^5
9. Weight: to be determined
10. Size: to be determined

The specific impulse values have been designated as program goals rather than a firm requirement.

2.2 DESCRIPTION OF DESIGN

The original electrothermal hydrazine thruster (EHT) upon which the present thruster is based is shown in Figure 1. The EHT design was modified by replacing the braze joint between the thrust chamber and nozzle with a threaded screen pack sleeve arrangement. This design, as illustrated in Figure 2, provides significant cost savings in thruster fabrication and will greatly implement performance optimization during the Evaluation Test Program. The design provides for

1. Component interchangeability
2. Changes in screen pack geometry
3. Changes in characteristic chamber length, L*, by varying the screen pack length or nozzle section length, or both
4. Nondestructive inspection, analysis, and cleaning of internal thruster components.

The additional thrust chamber and nozzle block mass associated with the threaded design will reduce the thruster's performance somewhat and increase the times required to reach holding and steady-state temperatures. These losses will be small and will not significantly affect the performance characterization tests performed in this feasibility study.

2.3 THRUSTER COMPONENTS

The thruster solenoid valve to be used during the Evaluation Test Program is the Wright Components, Inc. Model No. 15650 valve. This valve was successfully used on NASA/GSFC contract No. NAS5-11477. The injector-to-valve seal is accomplished by a Teflon compression sleeve.

Two 10.2 cm long by 0.114 cm diameter sheathed Aerorod heater elements are used to heat the thrust chamber and nozzle. These heater elements are sized to maintain holding temperatures in excess of 540°C for sea-level operation during portions of the Evaluation Test Program phase. Thruster insulation is provided by wrapping layers of Microquartz felt around the thrust chamber.

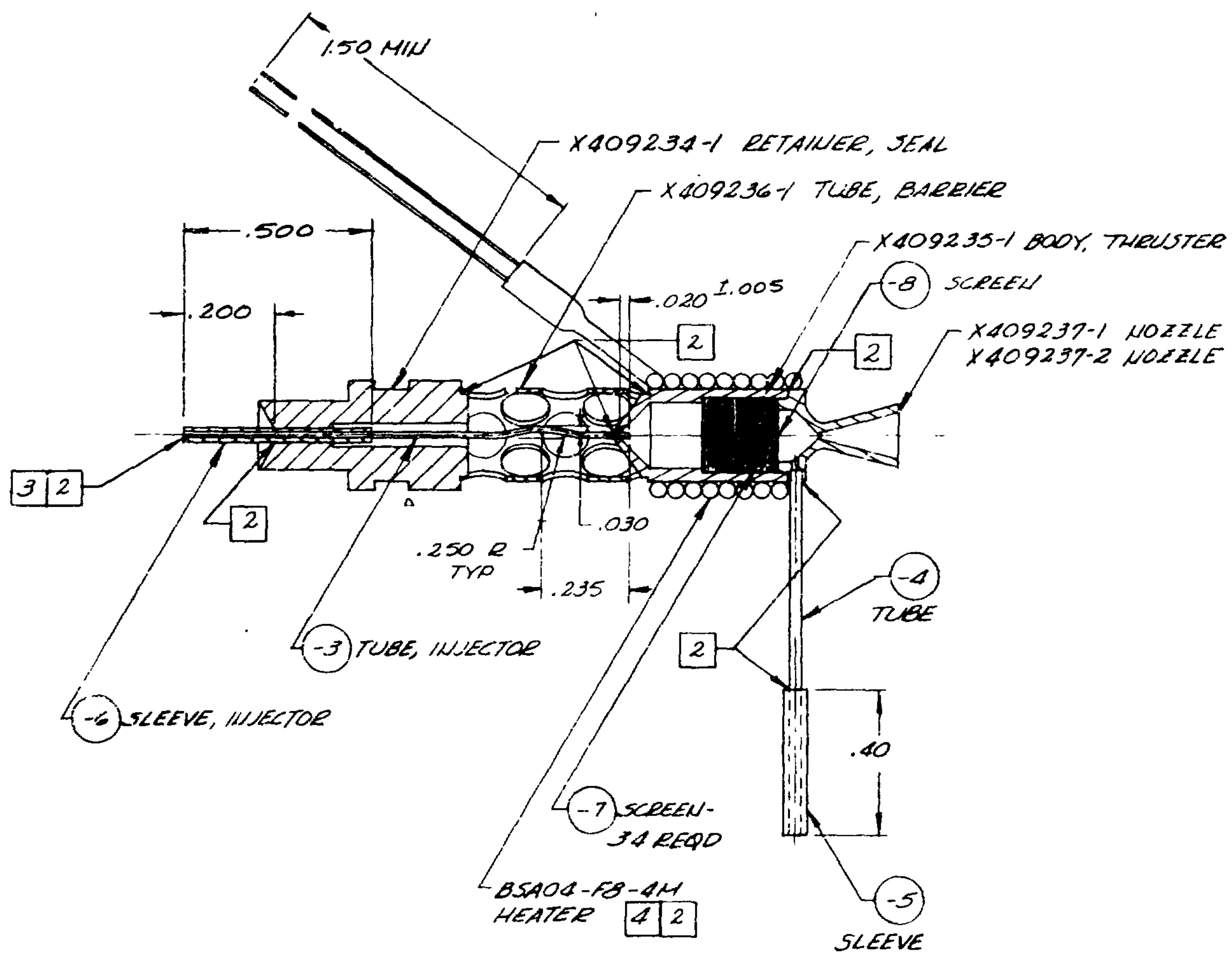


Figure 1. Electrothermal Hydrazine Thruster

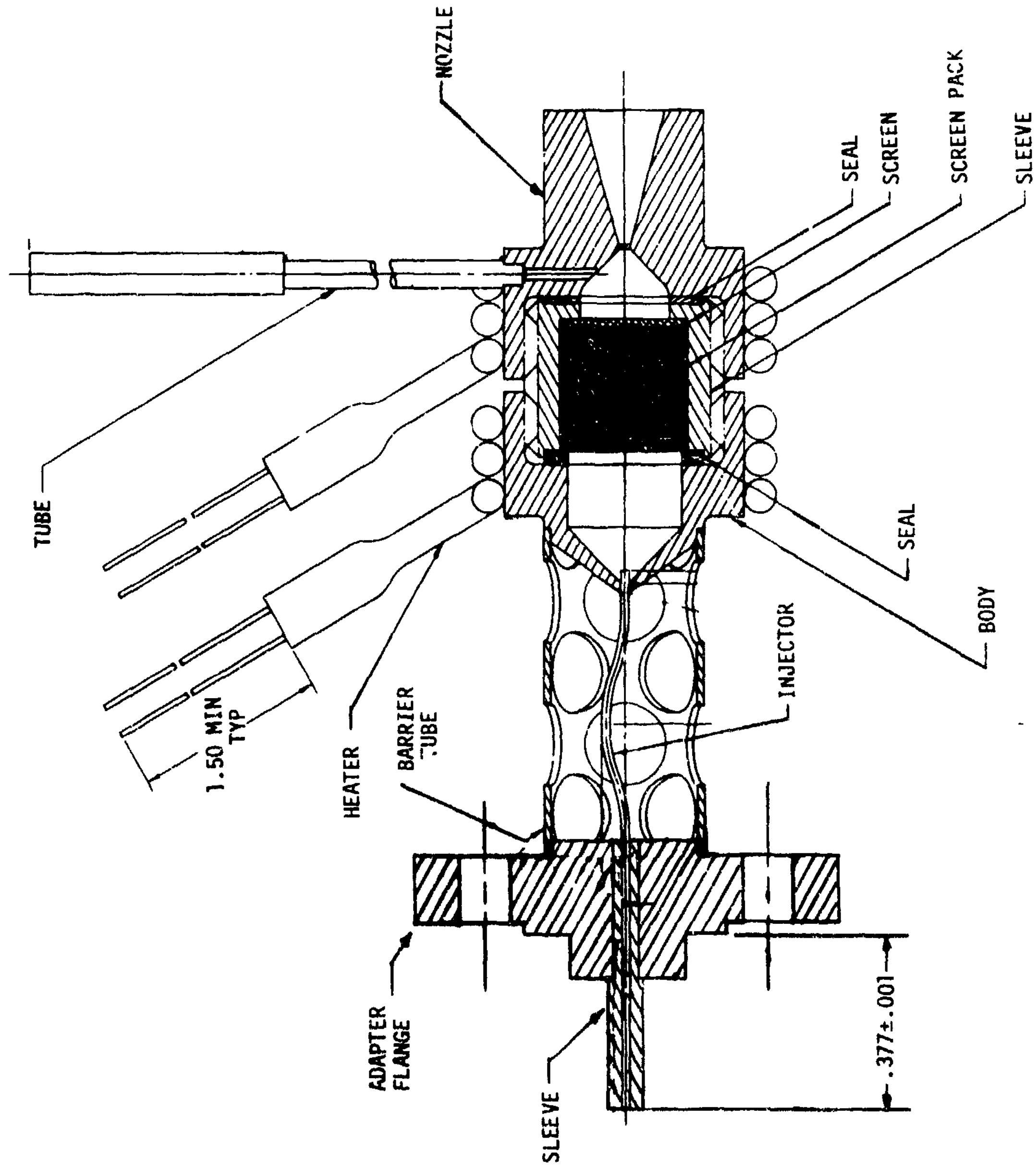


Figure 2. Monopropellant Demonstration Thruster

The nozzle is of standard convergent-divergent design with an area ratio of 50. The throat diameter is 0.046 cm. The screen pack sleeve is sized to accept 0.51 cm diameter platinum screens. The initial sleeve length is 0.51 cm. The chamber head end has a 90° included angle and a tapered wall thickness to limit heat transfer to the injector. The thrust chamber - screen pack - nozzle seals are of thin hardened copper.

The thruster is mated to the Wright Components, Inc. valves through a 0.025 cm thick thermal barrier tube and adapter flange.

Engineering drawings for the various demonstration thruster components are included in Appendix A.

3.0 FABRICATION

3.1 THRUSTER COMPONENTS

The fabricated components for five thrusters are shown in Figure 3. Included are the nozzle, screen pack sleeve, body, barrier tube, valve adapter flange and gasket seals. An assembled but not brazed view of the demonstration thruster configuration is presented in Figure 4. The injector tube and two heating elements are missing from Figure 4. All parts were fabricated from Haynes alloy L605 (Haynes 25) with the exception of the adapter flange (Type 304 stainless steel) and the gasket seals (No. 102 copper).

The injector tubes were fabricated from Haynes 25 tubing (0.0356 cm OD by 0.0152 cm ID). All injectors were built with a thermal relief bend rather than a complete loop. The chamber end of the injector was trimmed square and deburred on a jeweler's lathe.

The heater elements were wound in one layer on a mandrel slightly smaller than the outer diameter of the thruster body.

The screen packs were fabricated from 52 mesh platinum gauze and 40 mesh Haynes 25. The platinum screens (60) were punched and pre-compressed by the tooling shown in Figure 5. A single Haynes 25 screen was used as a

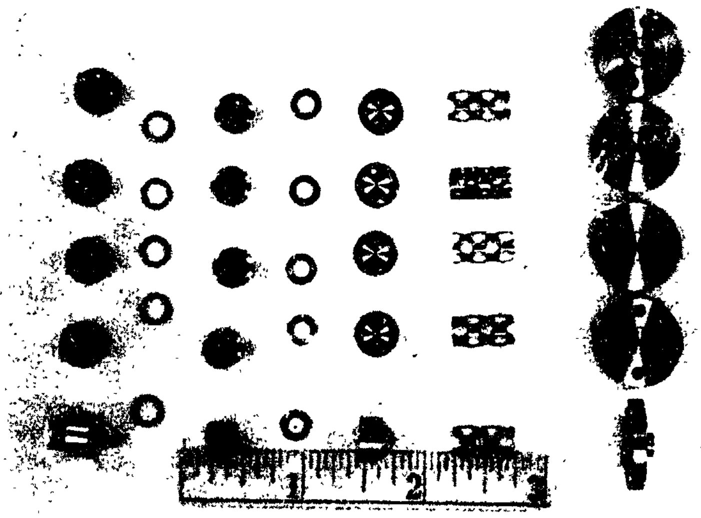


Figure 3. Demonstration Thruster Components

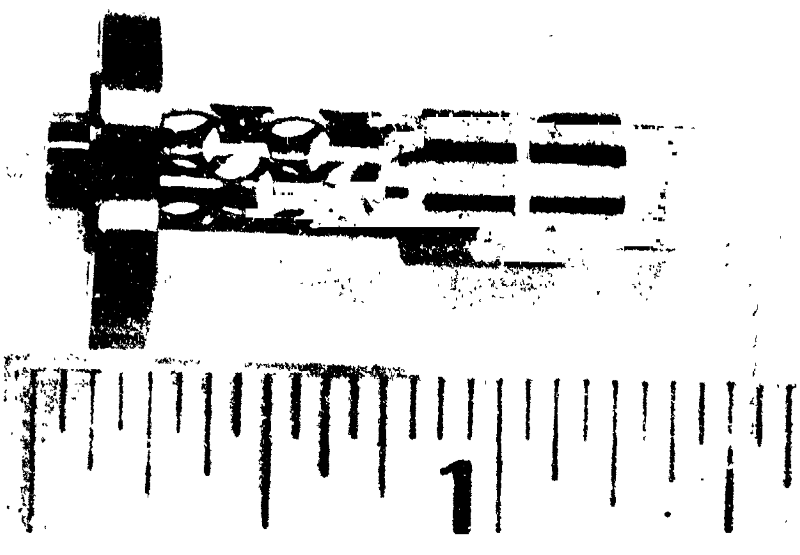


Figure 4. Demonstration Thruster Configuration

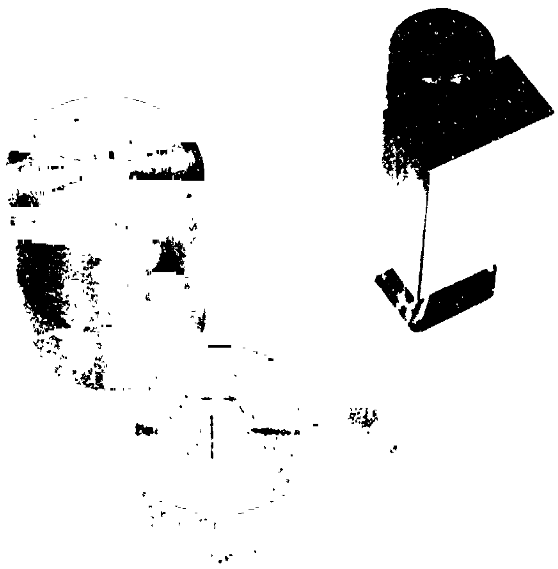


Figure 5. Screen Forming Tooling

retainer for the platinum screen pack. The Haynes 25 retainer was inserted into the screen pack sleeve towards the nozzle end of the thruster. The compacted platinum screen pack was then transferred directly from the compression die into the sleeve.

The split-chamber design allowed the thruster to be assembled in one high-temperature braze cycle. Nicrobraze alloy 21C was used for the entire assembly. A brazed thruster is shown in Figures 6 and 7 as dissassembled and assembled views.

4.0 NEW TECHNOLOGY

The modular design of the monopropellant demonstration thruster described in Section 2.2 of this report has resulted in substantial fabrication ccst savings and will enhance technical efforts during the Evaluation Test Program phase. The design is novel in electrothermal hydrazine thruster technology.

5.0 PROGRAM FOR THE EVALUATION TEST TASK

A detailed plan for the Evaluation Test Task of the Study of Monopropellants for Electrothermal Thrusters was submitted as Appendix B of the Analytical Task Summary Report[2].

6.0 CONCLUSIONS

The fabricated thruster assemblies will allow the rapid evaluation and characterization of monopropellants with freezing points lower than MIL-grade hydrazine. The design permits changes in the internal thrust chamber geometry in order to accommodate the different combustion characteristics of the monopropellants to be used during the Evaluation Test Task of this program.

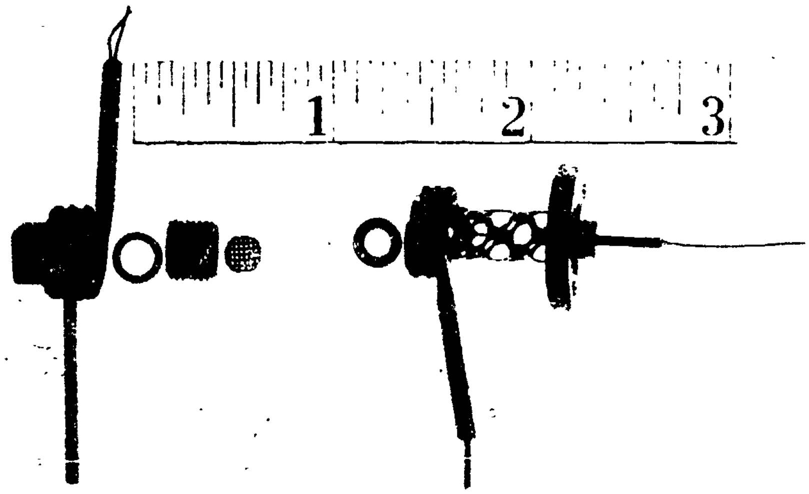


Figure 6. Disassembled Demonstration Thruster

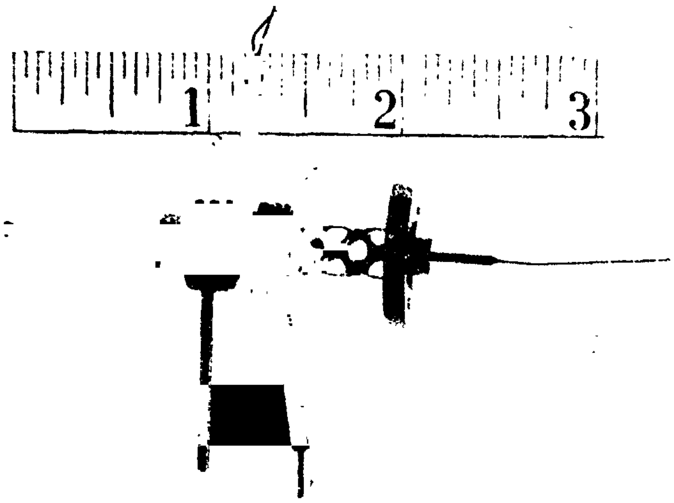


Figure 7. Assembled Demonstration Thruster

7.0 REFERENCES

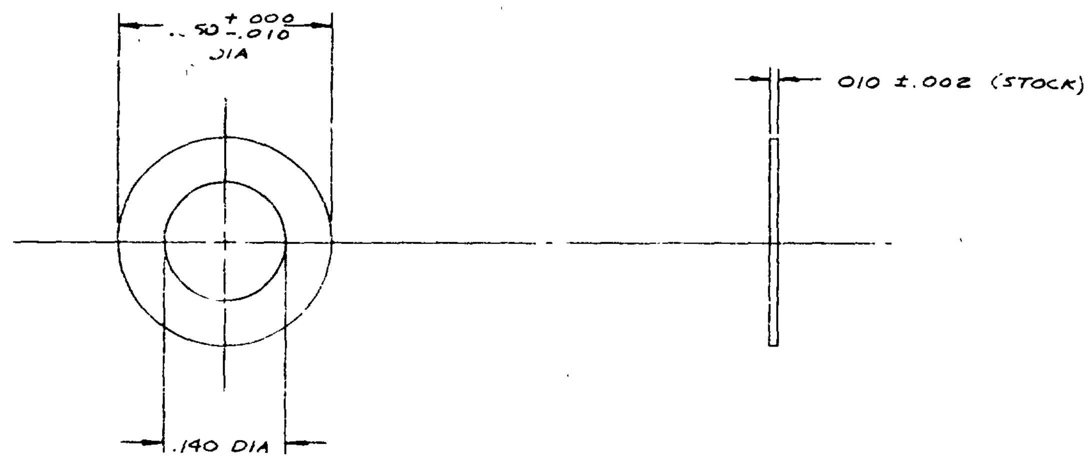
1. Monopropellant Hydrazine Resistojet, Engineering Model Fabrication and Test Task Summary Report, TRW Document 20266-6024-RO-00, March 1973.

2. J. D. Kuenzly and Rein Grabbi, Study of Monopropellants for Electrothermal Thrusters, Analytical Task Summary Report, TRW Document 22409-6010-RU-00, December 1973.

APPENDIX A

A complete set of monopropellant demonstration thruster drawings is included in this appendix.

(1)	Gasket	X412586-1
(1)	Gasket-Screen Pack	X412582-1
(1)	Body, Monopropellant Demonstration Thruster	X412581-1
(1)	Sleeve-Threaded, Monopropellant Demonstration Thruster	X412579-1
(1)	Nozzle, Monopropellant Demonstration Thruster	X412578-1
(1)	Tube, Barrier-EHT	X409236-1
(60)	Screen	X412580-15
(1)	Screen	X412580-14
(1)	Sleeve	X412580-13
(1)	Tube	X412580-12
(1)	Tube	X412580-11
(1)	Plate, Seal-EHT	X409383-1
(1)	Seal, Tube-EHT	X410563-1
(1)	Sleeve, Injector	X409240-9



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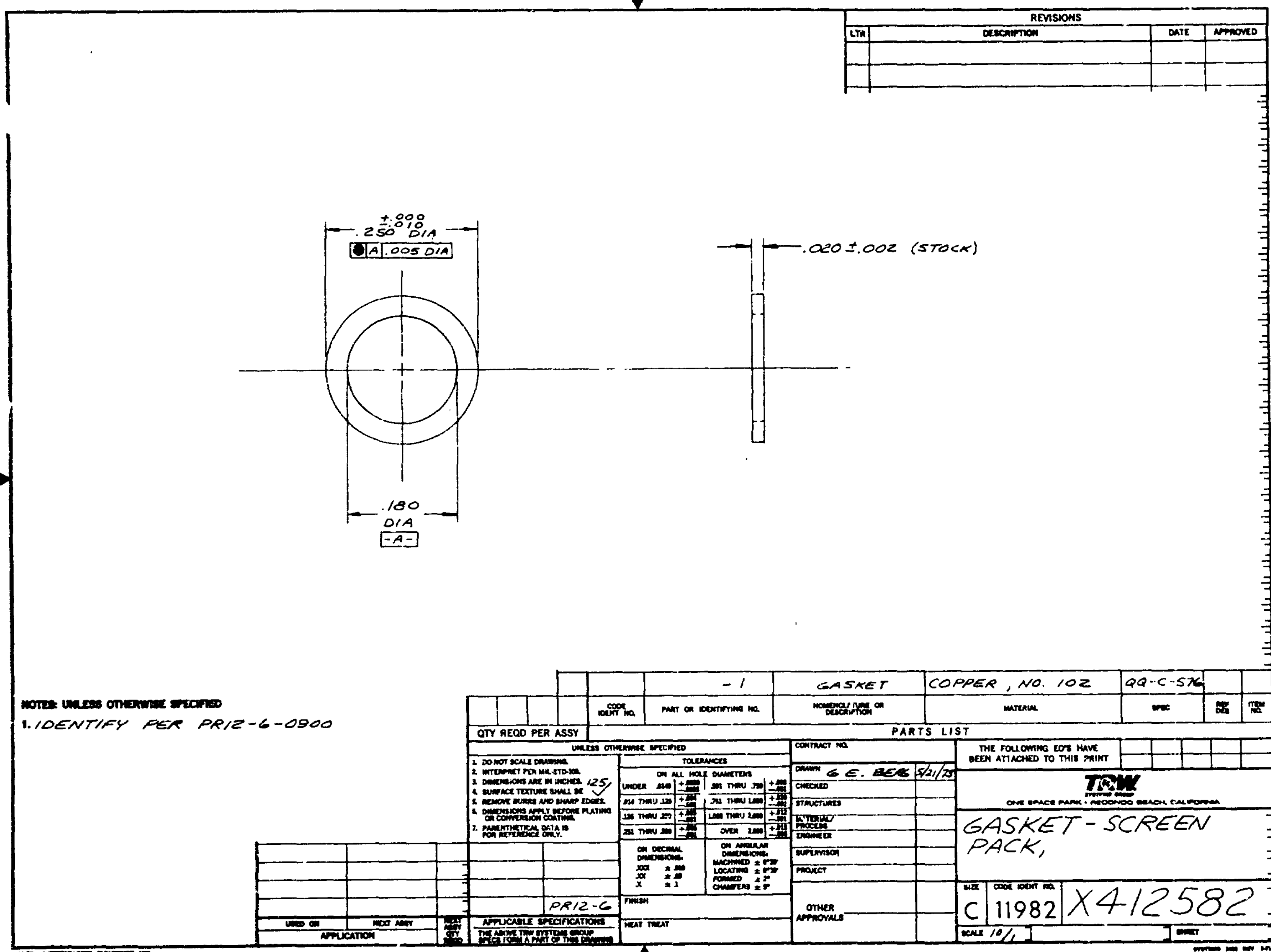
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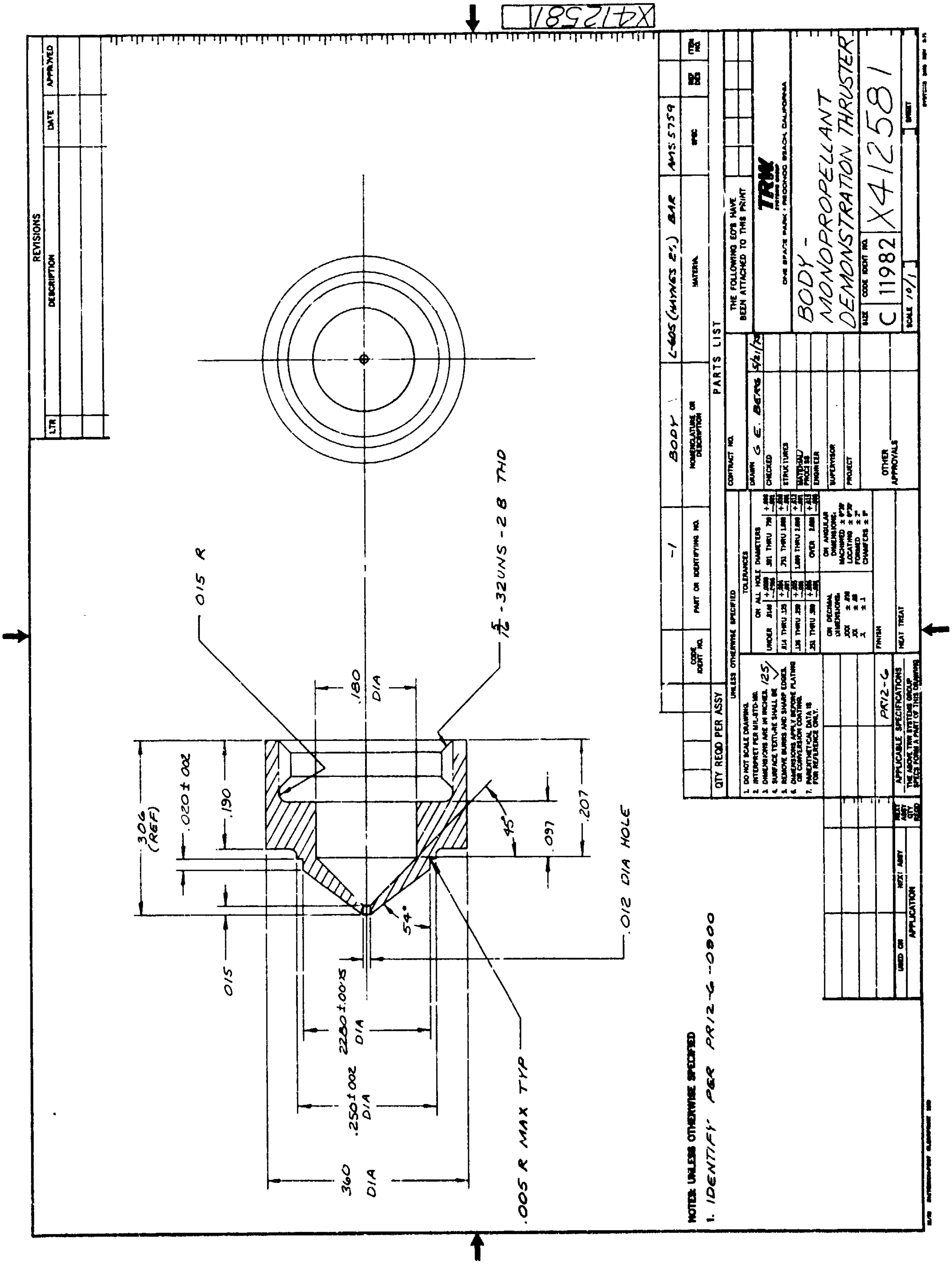
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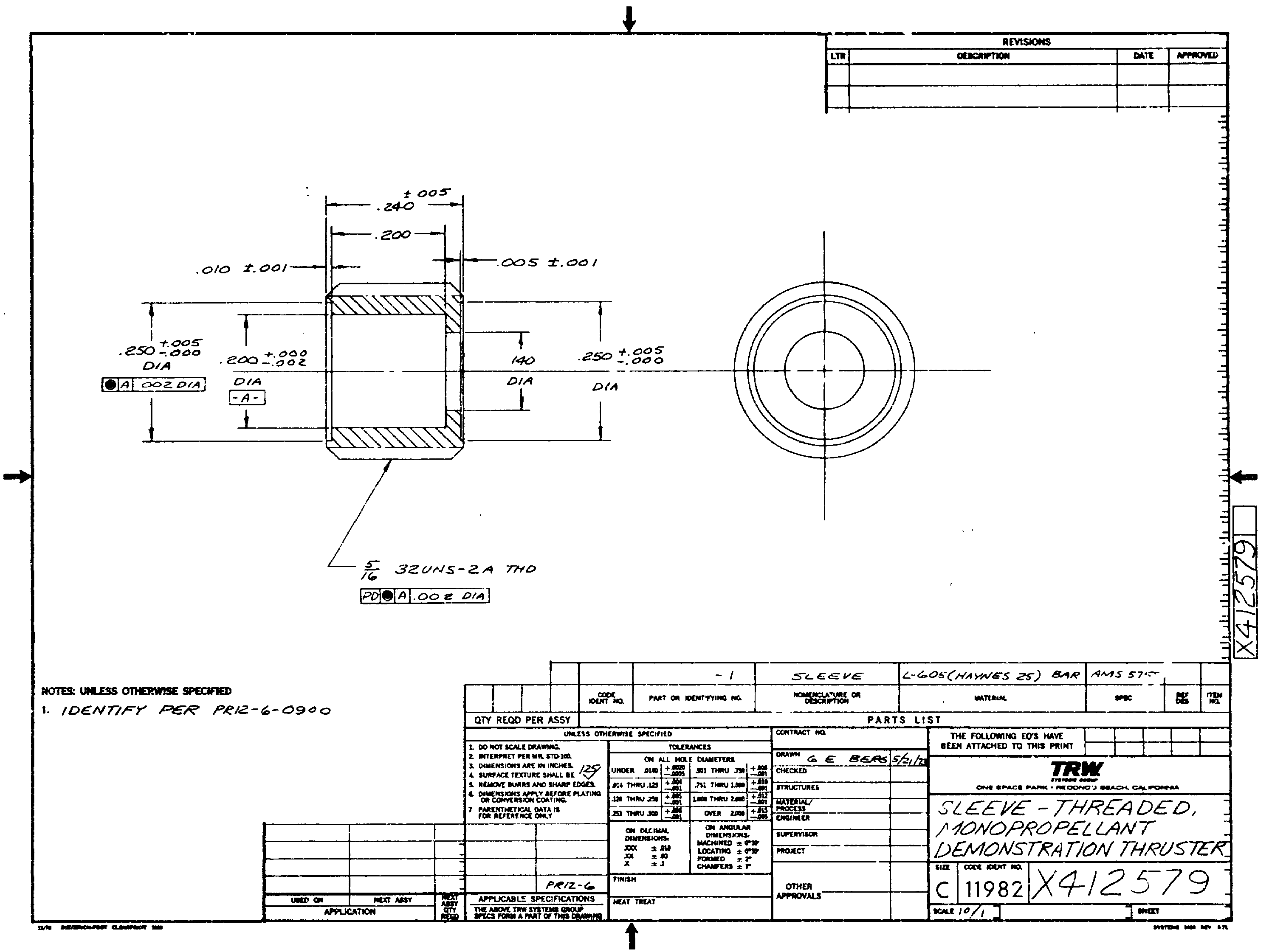
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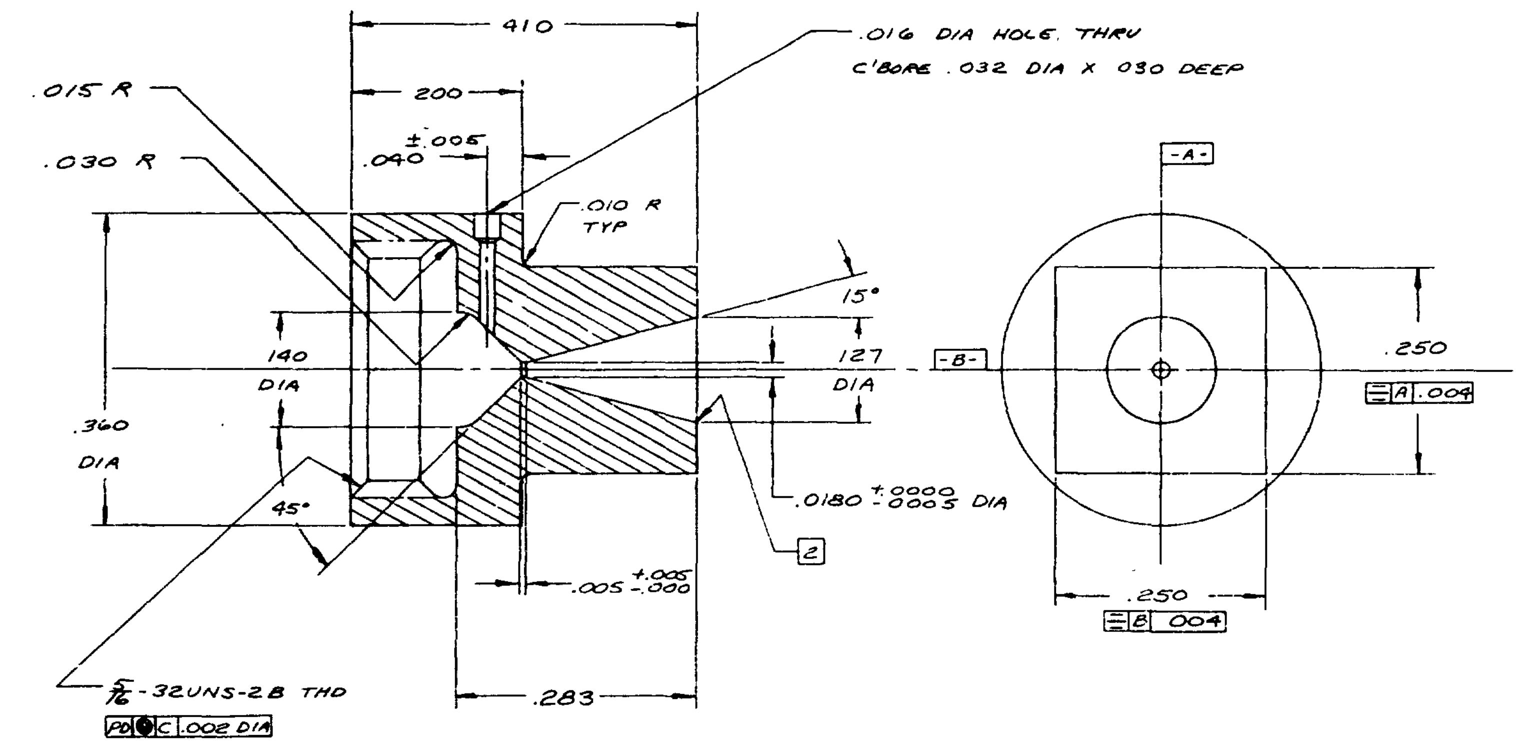

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NOZZLE - MONOPROPELLANT DEMONSTRATION THRUSTER

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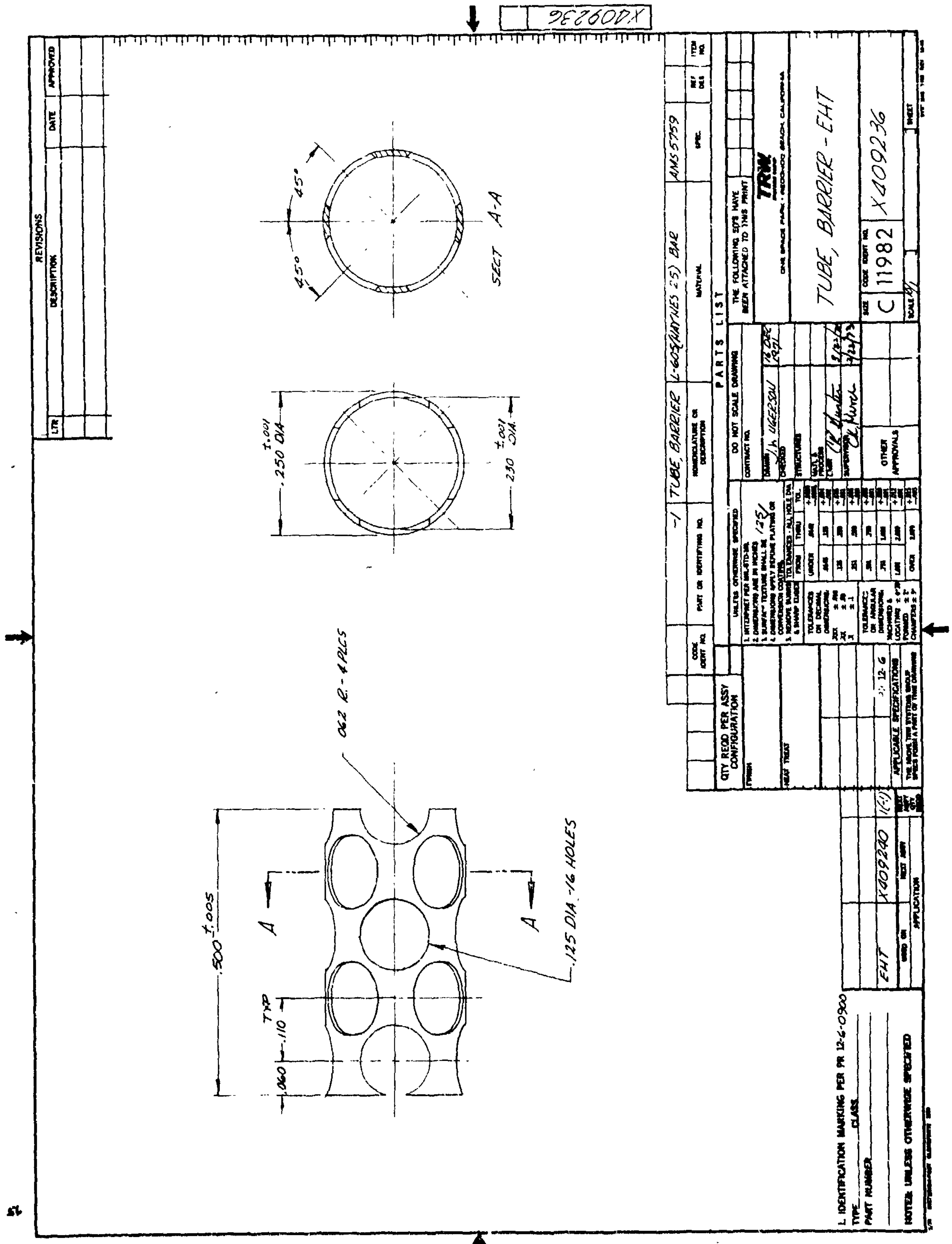

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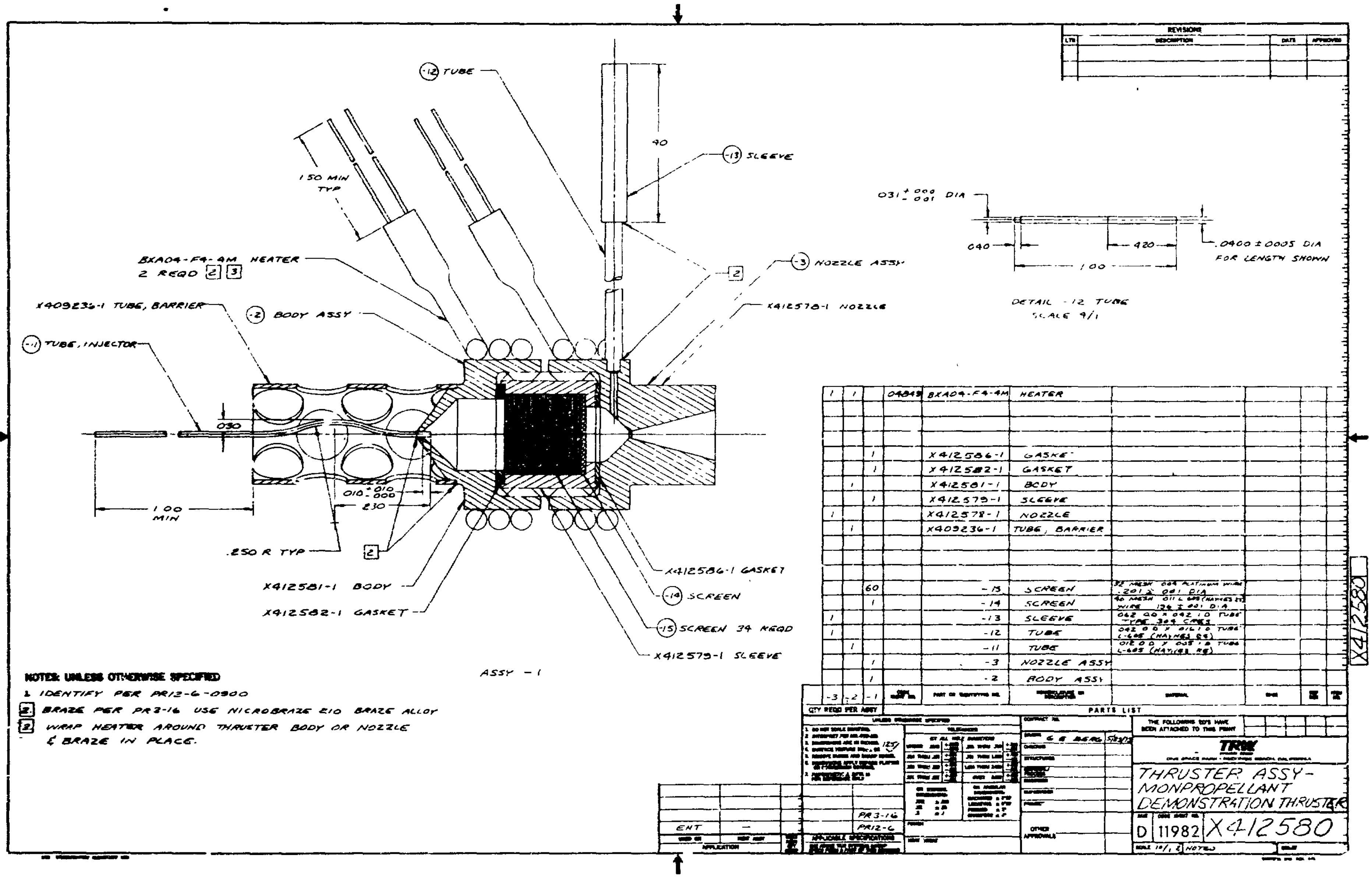
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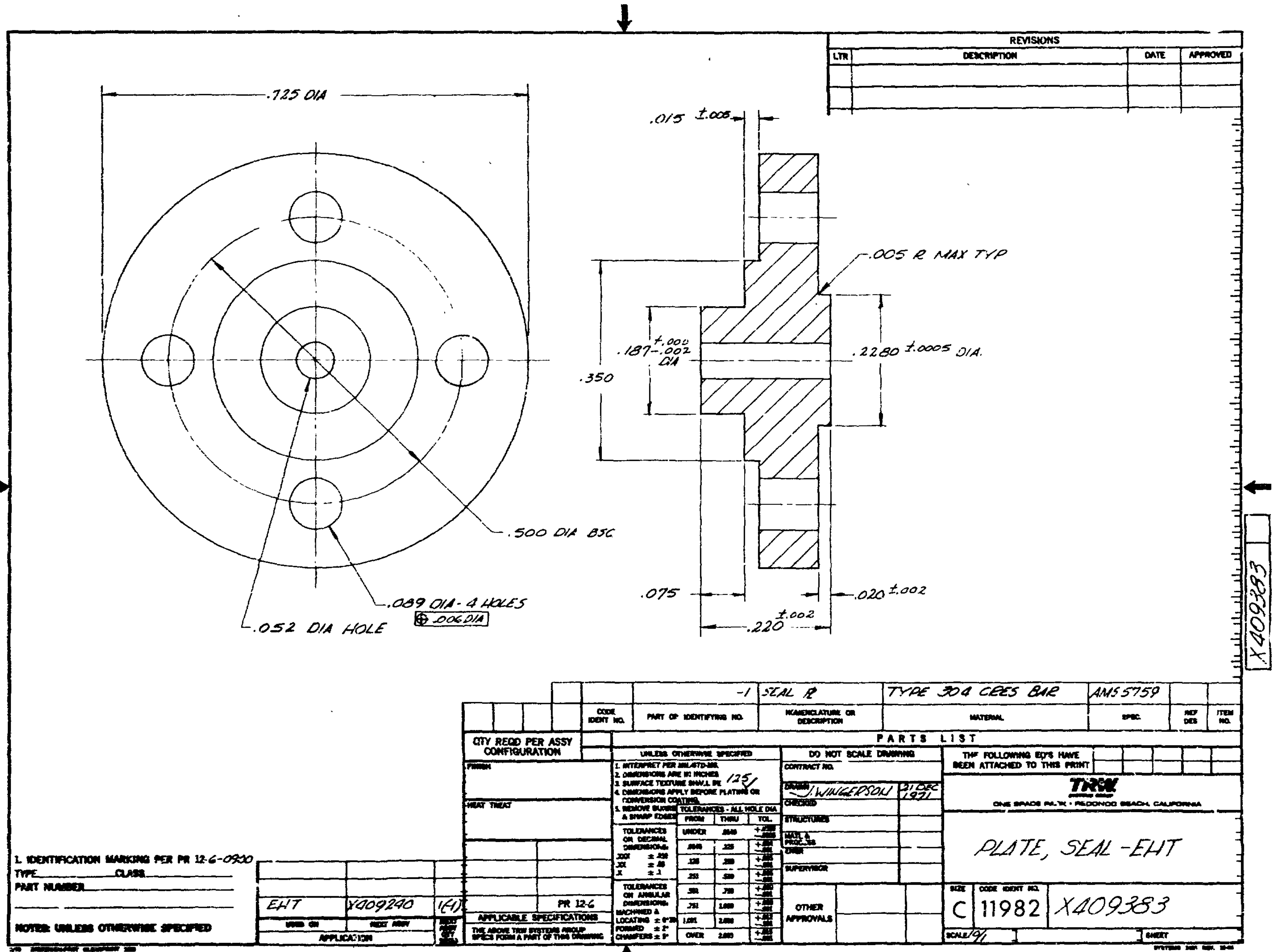
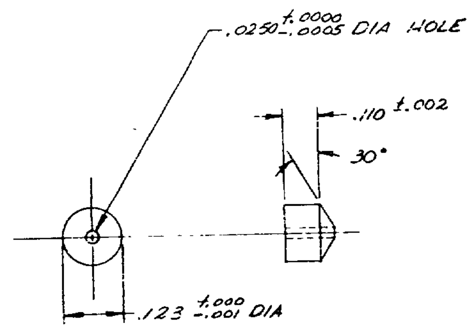
PR12-6
TRW
THRUSTER ASSY-
MONPROPELLANT
DEMONSTRATION THRUSTER
D 11982 X412580
X412580



REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
.725 DIA
.015 ±.005
.005 R MAX TYP
.187 +.000 -.002 DIA
.2280 ±.0005 DIA.
.350
.500 DIA BSC
.089 DIA - 4 HOLES
.006 DIA
.052 DIA HOLE
.075
.020 ±.002
.220 ±.002
X409383
-1
SEAL PL
TYPE 304 CRES BAR
AMS 5759
CODE IDENT NO.
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
MATERIAL
SPEC.
REF DES
ITEM NO.
PARTS LIST
QTY REQD PER ASSY CONFIGURATION
FINISH
HEAT TREAT
UNLESS OTHERWISE SPECIFIED
DO NOT SCALE DRAWING
THE FOLLOWING ED'S HAVE BEEN ATTACHED TO THIS PRINT
CONTRACT NO.
DRAWN J. WINGERSON 21 DEC 1971
CHECKED
STRUCTURES
SUPERVISOR
OTHER APPROVALS
TRW
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA
PLATE, SEAL - EHT
SIZE
CODE IDENT NO.
C
11982
X409383
SCALE 10/1
SHEET
1. IDENTIFICATION MARKING PER PR 12-6-0900
TYPE
CLASS
PART NUMBER
NOTES: UNLESS OTHERWISE SPECIFIED
EHT
X409240
1(-1)
USED ON
NEXT ASSY
APPLICATION
PR 12-6
APPLICABLE SPECIFICATIONS
THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING



NOTES: UNLESS OTHERWISE SPECIFIED
1. IDENT. MARKING PER PR 12-6-0900

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED

PARTS LIST

QTY REQD PER ASSY	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REV	ITEM NO.
		-1	SEAL	TEFLON ROD	MIL-P-19468		

UNLESS OTHERWISE SPECIFIED
1. DO NOT SCALE DRAWING.
2. INTERPRET PER MIL STD-100.
3. DIMENSIONS ARE IN INCHES.
4. SURFACE TEXTURE SHALL BE 125
5. REMOVE BURRS AND SHARP EDGES.
6. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
7. PARENTHETICAL DATA IS FOR REFERENCE ONLY.

TOLERANCES
ON ALL HOLE DIAMETERS

UNDER .0149	+.0020 −.0005	.501 THRU .750	+.008 −.001
.014 THRU .125	+.004 −.001	.751 THRU 1.000	+.010 −.001
.126 THRU .250	+.005 −.001	1.001 THRU 2.000	+.012 −.001
.251 THRU .500	+.006 −.001	OVER 2.000	+.015 −.005

ON DECIMAL DIMENSIONS: .XXX ±.010; .XX ±.03; .X ±.1
ON ANGULAR DIMENSIONS: MACHINED ±0°30'; LOCATING ±0°30'; FORMED ±2°; CHAMFERS ±5°

FINISH
HEAT TREAT

CONTRACT NO.
DRAWN J. Winderson 1/21/72
CHECKED
STRUCTURES
MATERIAL/PROCESS
ENGINEER [signature] 3/24/72
SUPERVISOR [signature] 3/22/72
PROJECT
OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

SEAL, TUBE EHT

SIZE C | CODE IDENT NO. 11982 | X410563
SCALE NONE | SHEET

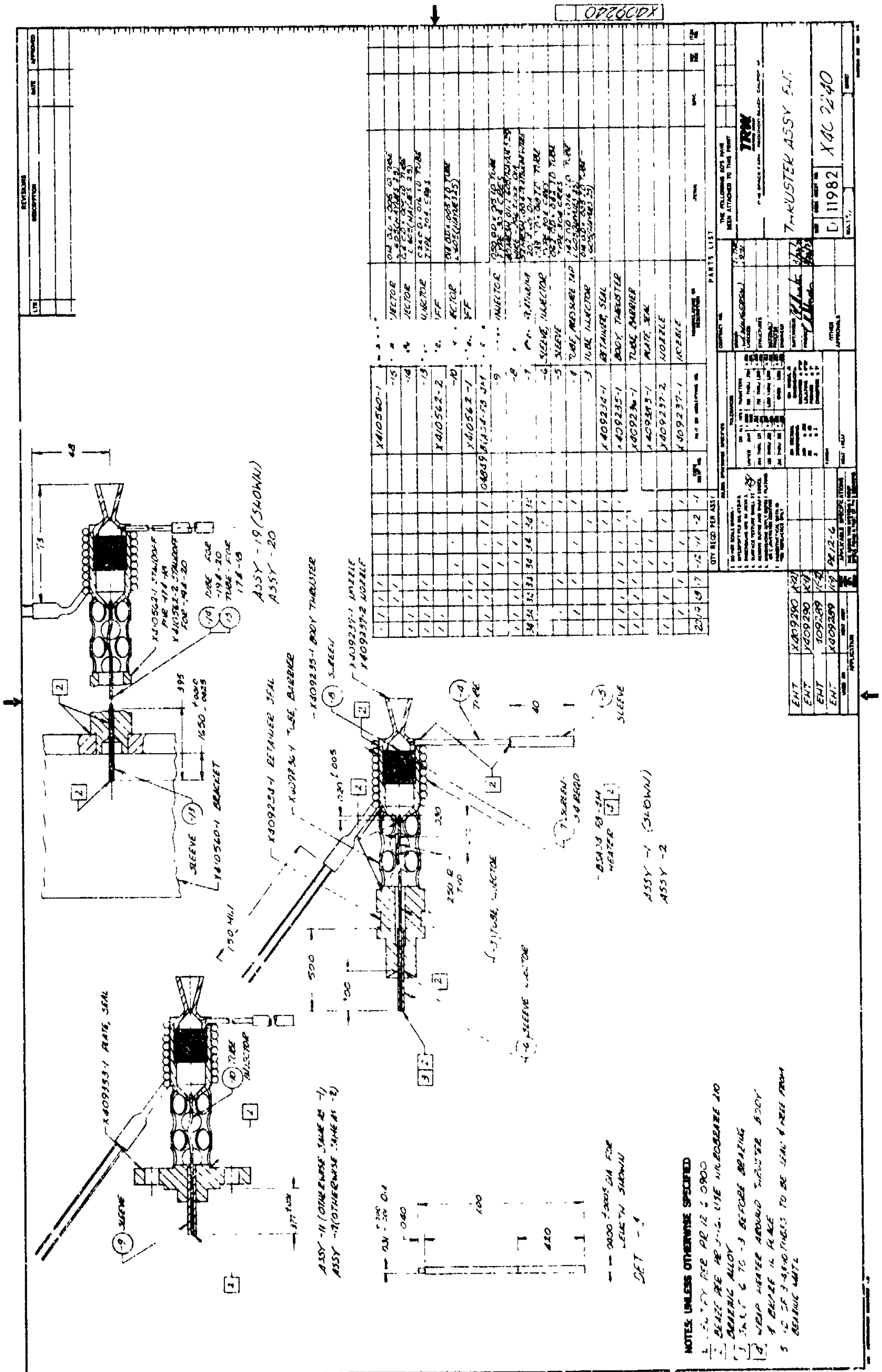
NEXT ASSY QTY REQD	APPLICABLE SPECIFICATIONS
1(-1)	PR 12-6

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

USED ON	NEXT ASSY
EHT	

APPLICATION

X410563


XAC 2240
PARTS LIST
NOTES: UNLESS OTHERWISE SPECIFIED
11982